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APPLICATION OF THE GIFTS-5 MINIBASED GRAPHICS SYSTEM FOR SHIP DESIGN AND ANALYSIS

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APPLICATION OF THE GIFTS-5 MINI-BASED
GRAPHICS SYSTEM FOR SHIP DESIGN AND ANALYSIS

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University of Arizona, Tucson.

INTRODUCTION

The GIFTS finite element structural analysis system has been developed with the support of the Office of Naval Research, the U.S. Coast Guard, and members of the GIFTS Users Group (GUG). It is a graphics-oriented collection of programs, which operate on a standardized data base. The system is designed to fit in a relatively small core area, and is specifically suited to time sharing and mini-computer systems. It may be used as a stand-alone finite element package or as a pre- and postprocessor for other systems.

CAPABILITIES OF GIFTS 5

A. Model Generation. Automatic model generation and interactive model editor. Generation of parametric lines with equally, or unequally spaced points, generation of three- and four-sided surface patches, covered with triangular or quadrilateral elements of arbitrary order. Generation of line structural elements of arbitrary order, including a sophisticated library of beam elements. Generation of six-sided and five-sided solid regions, filled with first order solid elements.

B. Model Display. Display of model outlines or detailed element plots. Choice of absolute viewing direction or incremental rotations. Labelling by user of system point number, element number, element type, material or thickness number. Introduction of perspective. Selected display by boxing parallel to model or display axes. Selective elimination of surface patches. Selective plotting of point or element slices in solid regions.

c. Generation and Display of Load and Boundary Conditions. GIFTS is capable of load and boundary condition generation on surface patches, lines or points, as well as inertial loading due to translational acceleration or angular velocity. The user may obtain plots of loads and moments applied to the model, in the form of arrows, whose scale may be influenced by the user. The model freedoms may be displayed in the form of vectors, superimposed on the model. Prescribed displacements and freedom-to-freedom constraints may be introduced by the use of Lagrange constraints.

D. Displacement and Stress Display. A plot of the deformed model, with automatically scaled displacement, may be produced once the deflections have been computed. All model plotting options are applicable. In addition, the user may change the displacement scale, or create composite loading cases by linearly combining a number of loading cases. Labelled stress contours may be plotted within the area being viewed. Principal stresses may be displayed as vectors showing direction and magnitude. Symbols denoting stress level may also be used. For beam elements applied forces and resultant shear and moments diagrams over the length of the beam element are displayed. A detailed plot showing normal stress and shear stress distributions over the cross-section may be produced at any point along the beam's length.

E. Static Analysis. The GIFTS 5 analysis package supports a library of basic first order elements encompassing a rod element, a general purpose beam element, triangular and quadrilateral membrane elements, triangular and quadrilateral axisymmetric elements, triangular and quadrilateral bending elements and constrained substructures as well as second order rod, triangular and quadrilateral membrane and triangular and quadrilateral axisymmetric elements. Matrix partitioning is utilized to set up and solve the equations. Several nodes are lumped together in each partition to increase solution efficiency. A band- width optimization program is included, although the program is not band width limited.

F. Substructuring. The program has substructuring and
    constrained   substructuring   capabilities.   The
    substructure boundaries may be kinematically
    constrained   using   rigid   linear   or   cubic
    constraint   functions..   Substructures   and/or
    constrained substructures may be assembled,
    together with ordinary finite elements to form a
    model. After model analysis,- it is possible to
    request a local analysis of any individual
    substructure.

G. Vibrational Mode Analysis. GIFTS 5 uses the
    subspace iteration method to obtain a number of
    the lowest vibrational frequencies and modes of
    an arbitrary structure. Stresses may also be
    computed.

H. Transient Response Analysis. It is possible to
    apply a time varying load to a structure, and
    compute the deflection and stress histories.
    GIFTS uses the Houbolt scheme (third order
    backward difference).

I. Axisymmetric Solids. GIFTS 5 is capable of solving
    axisymmetric models under either axisymmetric
    loads, or non-axisymmetric loads broken down into
    a Fourier series.

J. Thermal Stress. A temperature field may be defined
    for any structure being, analyzed, and GIFTS 5
    will compute the resulting thermal stresses. It
    does not, however, have heat flow analysis
    capability.

K. Retrieval of Numerical Information. Apart from
    graphic display, GIFTS may be used to extract
    practically any subset of information from the
    data base and print it in an organized manner on
    the screen, or on a line printer.

L. Error Detection. Extensive checks are performed
    throughout the system to protect the user against
    his own mistakes. User oriented error and warning
    messages are printed out wherever appropriate.

MACHINE INDEPENDENCE

   GIFTS 5 is written exclusively in FORTRAN IV. A computer
word length of 16 bits or more is assumed. No more than four
alphanumeric characters are stored in one word. Hollerith
constants appear only in DATA statements. All real variables
are single precision and no complex variables are used. Disk

files are either sequential or index sequential. In an index
sequential file it is assumed that any record may be read or
written at random. Most files are blocked for I/O
efficiency. Core buffers may contain more than one block.
Plotting commands to the terminal are "graphics primitives,"
and can be easily interfaced to any existing graphics
package or, better still, implemented directly. GIFTS-5
includes its own special purpose FORTRAN written Tektronix
terminal driver. GIFTS-5 versions are available for the Data
General ECLIPSE-S/230, the DEC-10 and DEC-20, the PDP-11 and
the PRIME family of comuters. Versions are under
preparation for the CDC 6000 series, the IBM-370 series,
UNIVAC and VAX-11/780 computers.

DOCUMENTATION

   The program/listings contain extensive commenting, which
makes GIFTS 5 essentially self-documenting. In addition,
however, the following manuals are available:

   GIFTS PRIMER -- Contains an introduction to the finite
element method and the GIFTS system. The text is illustrated
by a number of solved simple examples.

   USER'S REFERENCE MANUAL -- A document describing the
program operation, instruction set, conventions used and so
on.

   THEORETICAL MANUAL -- Contains element formulation, and a
description of all numerical procedures used in the various
solution modules.

   SYSTEMS MANUAL -- Contains a detailed description of the
Unified Data Base, and key information to the system design.

   MODELLING GUIDE -- A discussion of modelling efficiency,
supported by many examples and comparison with classical
solutions.

INTERFACING GIFTS TO OTHER PROGRAMS

   It is a relatively easy task to interface GIFTS to any
other finite element programs. After the pre-processing is
complete, a program has to be written to extract the
relevant data from the GIFTS data base, create an input file
for the FEM program, and initiate its execution. It is
assumed that the program will place results on an output
tape. This output tape can then be read by another interface
program, which then feeds the data back into the GIFTS Data
Base for further processing and display. Interfaces exist
for SAP-IV and ANSYS. Others are being prepared for NASTRAN,
STAGS, DAISY and SAP-V.

DISTRIBUTION OF GIFTS 5

GIFTS 5 has been supported by the Office of Naval Research and the United States Coast Guard. It is in the public domain and may be obtained from the University of Arizona for a reasonable charge. Users Groups exist both in the United States (UGUG) and in Europe (EGUG).

POTENTIAL IN SHIP ANALYSIS AND DESIGN

Although the program is being applied regularly to practical ship structure analysis by many organizations, it is somewhat difficult to produce realistic examples of its use in a university environment. Nevertheless, a set of examples are included, which clearly demonstrate the suitability of the program for typical ship structure analysis efforts. These examples span the spectrum from simple beam idealization of a complete tanker hull, to a detailed analysis of a full ship using substructures.

Analysis of a Stiffened Bulkhead.

Figure 1 shows a three-dimensional view of one half of a vertically stiffened bulkhead of, say, an oil tanker. Only one half is modeled because of symmetry. The problem was generated and solved using GIFTS-5 on an ECLIPSE-S/230 minicomputer, running in a time-sharing mode. The model has a total of 195 nodes and 322 elements, 154 of which are beam stiffeners and 168 quadrilateral shell elements. The problem has a total of 839 active degrees of freedom, with a maximum half band width of 106, and a computational (r.m.s) half band width of 76.

Figure 2 shows the commands necessary to generate the model, and apply boundary conditions and loads to it. These commands may be entered either interactively or via a file. The loads produced by the second set of commands are displayed in figure 3, and represent hydrostatic pressures from a partially filled center tank, and a full wing tank. The translational degrees of freedom, showing both symmetry conditions and support from the deck, bottom, side-shell and longitudenal bulkhead appears in figure 4.

The deflections of the bulkhead are shown in figure 5. Stress contours are displayed in figure 6. Load, shear force bending moment and torque diagrams can be displayed for any stiffener element (see figure 7), and detailed stress distribution at any position along the element may be shown (see figure 8).

The analysis, on the time shared minicomputer, cost approximately 40 dollars, based on a standard charging algorithm. The computer time requirements are given below:

Stiffness computation   608   CPU seconds
Decomposition   394   CPU seconds
Deflection computation   101   CPU seconds
Stress computation   62   CPU seconds

Total residence time   41 minutes wall clock time
            (other jobs running simultaneousely)

Two Dimensional Membrane Analysis of Webframe.

Figure 9 shows the subdivision of a webframe structure into grids, in preparation for the mesh generation procedure. Figure 10 gives the resulting stress contours. Such an analysis is typical of day to day applications. The. mesn generator provides a basic arrangement of nodes and elements, which may be then edited using the GIFTS editing module, to introduce local changes, such as stiffeners.

Analysis of an Idealized Bulk Carrier Using Substructuring.

This analysis was conducted as a term project by two students at the university. A typical bay of the ship was modeled using substructures, each involving up to 700 degrees of freedom, see figure 11. These substructures are then repeated over the parallel midside portion of the ship, and the fore and aft portions were completed using ordinary shell finite elements to give the complete structure, see figure 12. The problem was run on the PDP-15 minicomputer using the GIFTS-3 package. Results included overall behavior of the model as well as detailed, stress and deflection results in the individual substructures. Results are not shown here due to space considerations.

Analysis of Tubular Joints

Tubular joints are of importance, particularly in the case of offshore structures. The constrained substructure technique is used here to provide both overall behaviour and detailed stress distributions at the joints. In this case a two-dimensional tubular frame was modeled using beam elements, except at the joints, where a more detailed substructure was employed, see figures 13 and 14. Constraint conditions were applied at the substructure/beam interface to ensure compatibility. The results show the deflections of the frame under load, see figure 13, as well as the stress distribution in the joint, see figure 15.

CONCLUSIONS

A general purpose interactive, graphics oriented, finite element program has been described, which has applications in ship structure analysis, both static and dynamic, as well as in preliminary ship design. Its suitability for minicomputer application, as well as its dual role as a pre- and postprocessing and an analysis tool, give it a certain uniqueness in today's increasingly minicomputer dependent engineering environement.

ACKNOWLEDGEMENTS

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      Modelling Guide and GIFTS Primer,
      Interactive Graphics Engineering Laboratory,
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      ONR Technical Report No. 1, Contract No. N00014-75-C-0837,
      April, 1976.

(3)   H. A. Kamel and M. W. McCabe,
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      and its Relationship to the-Design Data Base,
      Presented at the first International Symposium on
      Computer-Aided Hull-Surface Definition, SNAME,
      Annapolis, Md., September 26-27, 1977.

[4]   H. A. Kamel and M. W. McCabe,
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      Optimum Design of Finite Element Software Subject to Core
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      N00014-75-C-0837, April 1978.
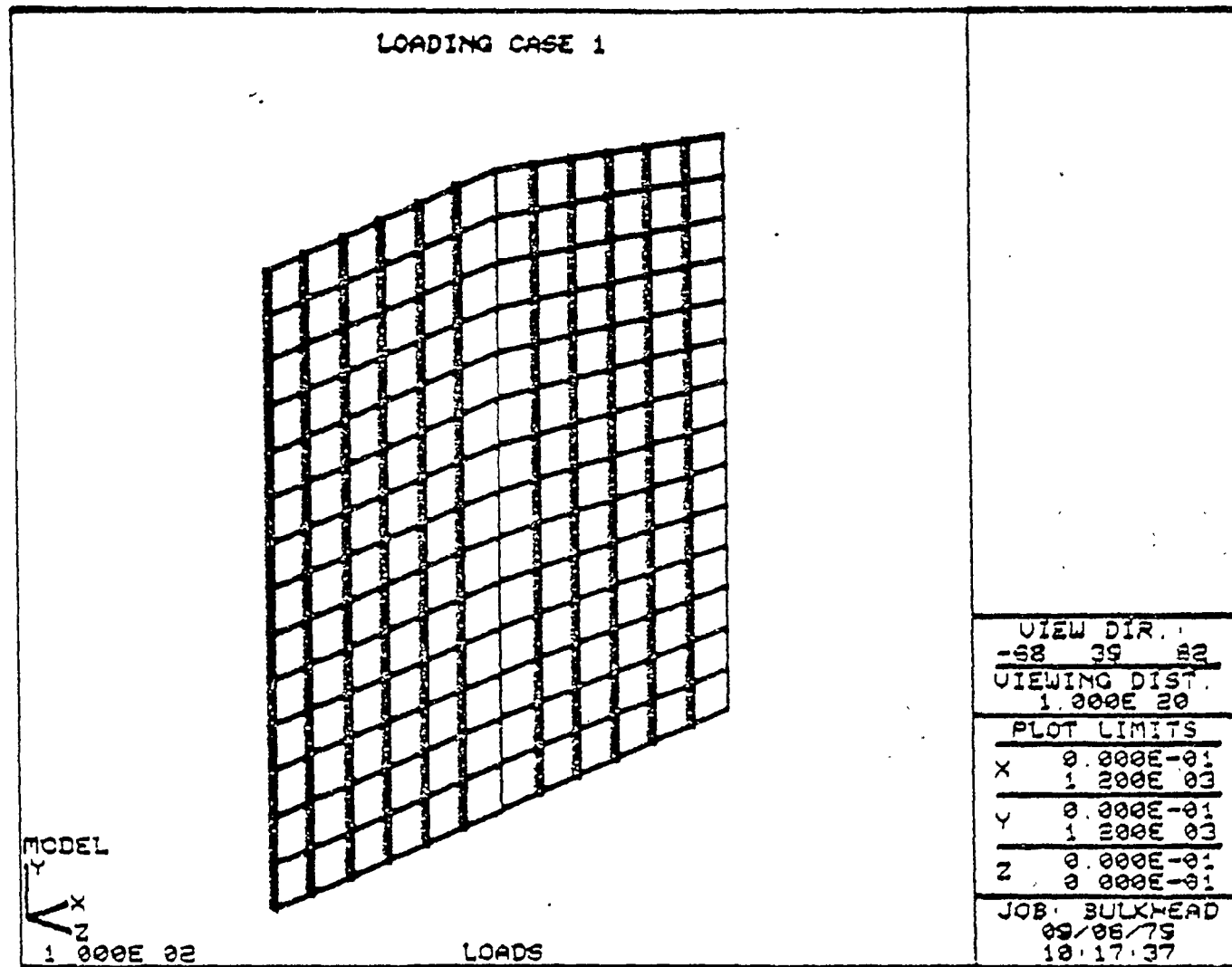
Figure 1. Finite Element Model of a Stiffened Bulkhead

```
MSTEEL/l/0
ETH,1/1/0.8,/0
TBEAM,10/2/30,20/0.7,0.9/0,0/0
KP0INT/1/,,/2/600,,/3/1200,,/4/0,1200/5/600,1200/6/1200,1080/0
LETY/BEAM2/1,2
SLINE/L12/l,2,7/L23/2,3,7/L45/4,5,7/L56/5,6,7
L25/2,5,15/L36/3,6,15/  /
SLINE,1/L14/1,4,15/5/  /
GETY/QB4/1,1
GRID4,2/G1/L12,L25,L45,Ll4/G2/L23,L36,L56,L25/  /
END
```

Commands to Generate Structural Model

```
SUPG,6/Gl/G2/ /
SUPL,l/L14/L45/L56/Ll2/L23/
SUPL,2/L25/L36/
SUPL,3/Ll2/L23/L36/L45/L56/L25/
SUPL,5/L14/
LDCASE/l
HEADG,2/Gl/0.,0.8/800.,0./Gl/0.,-0.6/600.,0./  /
LDCASE/2
HEADG,2/G2/0.,0.6/600.,0.,-0.8/800.,0./   /
LDCASE/3
HEADG,2/Gl/0.,0.8/800.,0./Gl/0.,-0.6/600.,0./  /
HEADG,2/G2/0.,0.6/600.,0./G2/0.,-0.8/800.,0./  /
END
```

Commands to Apply Boundary Conditions and Loads
                To Bulkhead

   Figure 2. Commands for Model, Boundary Condition and
            Load Generation for Stiffened Bulkhead
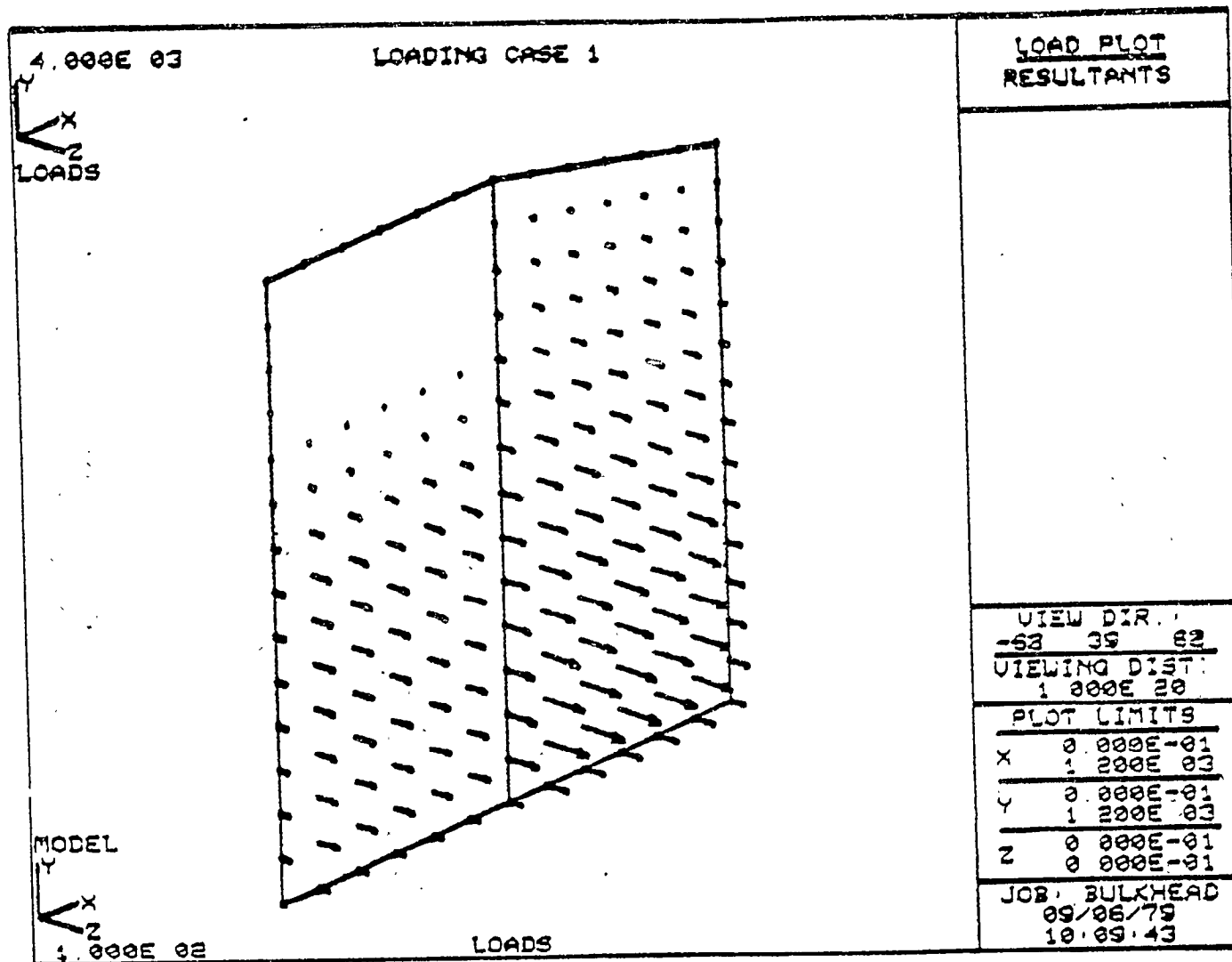
Figure 3. Hydrostatic Pressure Loading on Transverse Bulkhead
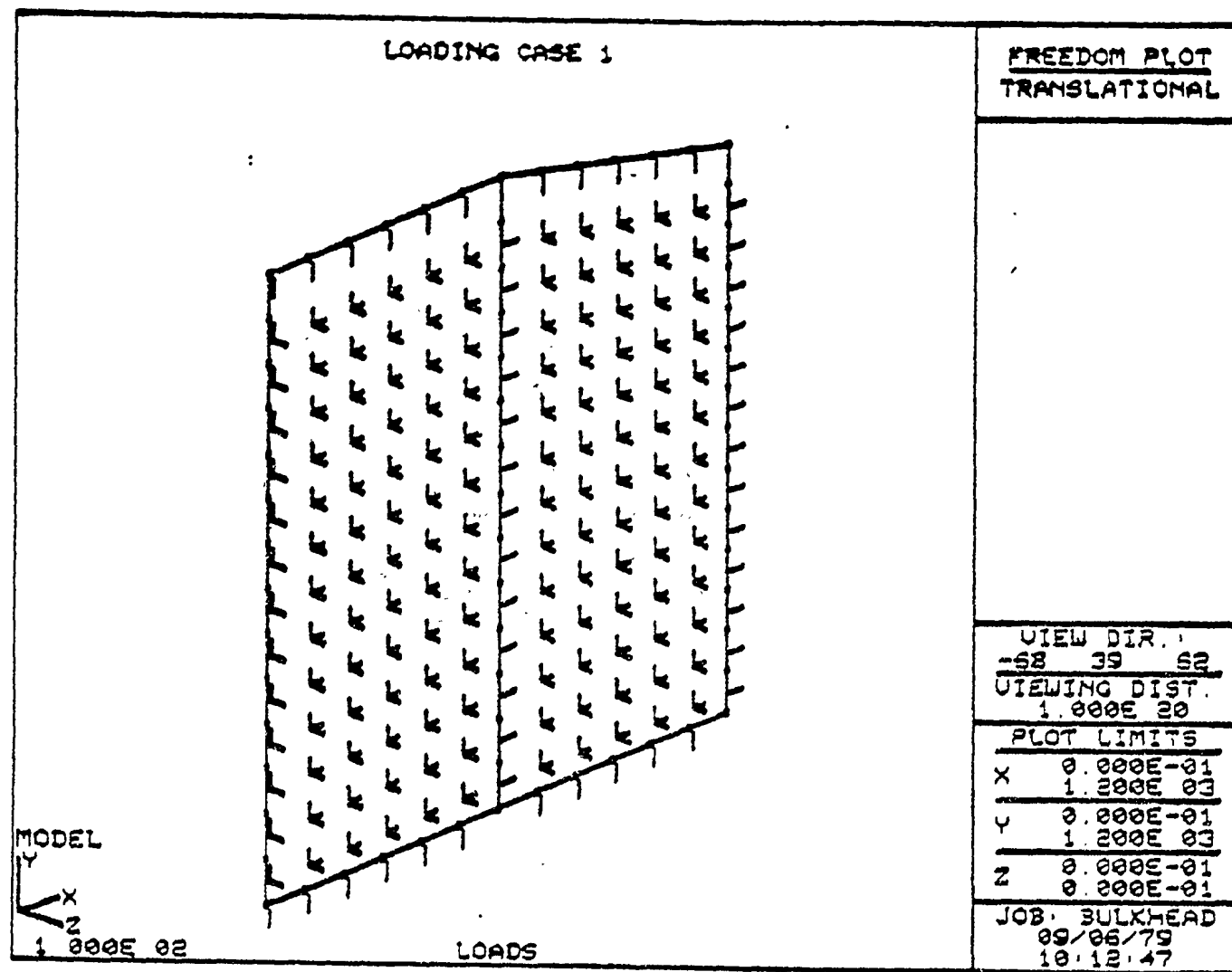
Figure 4. Translational Freedom Pattern for Bulkhead Model

LOADING CASE 1

VIEW DIR.		
-68	39	62
VIEWING DIST
1 000E 20
PLOT LIMITS
X	0.000E-01	
	1 200E 03	
Y	0.000E-01	
	1.200E 03	
Z	0.000E-01	
	0 000E-01	
JOB BULKHEAD
09/06/79
10.25.06

MODEL

DEFLS

1 000E 02   DEFLECTIONS   1 000E 00
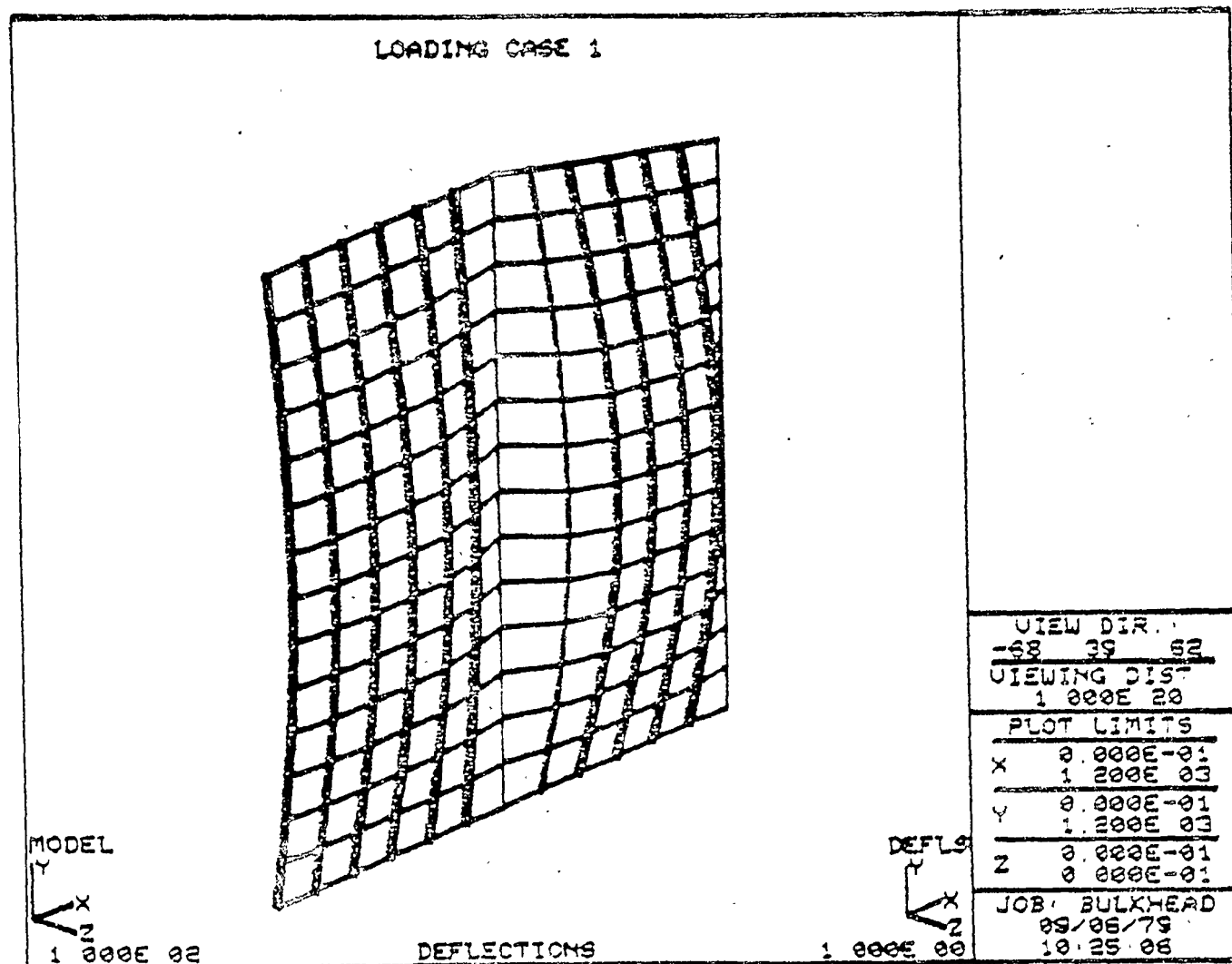
Figure 5. Deflections of Bulkhead under Hydrostatic Pressure
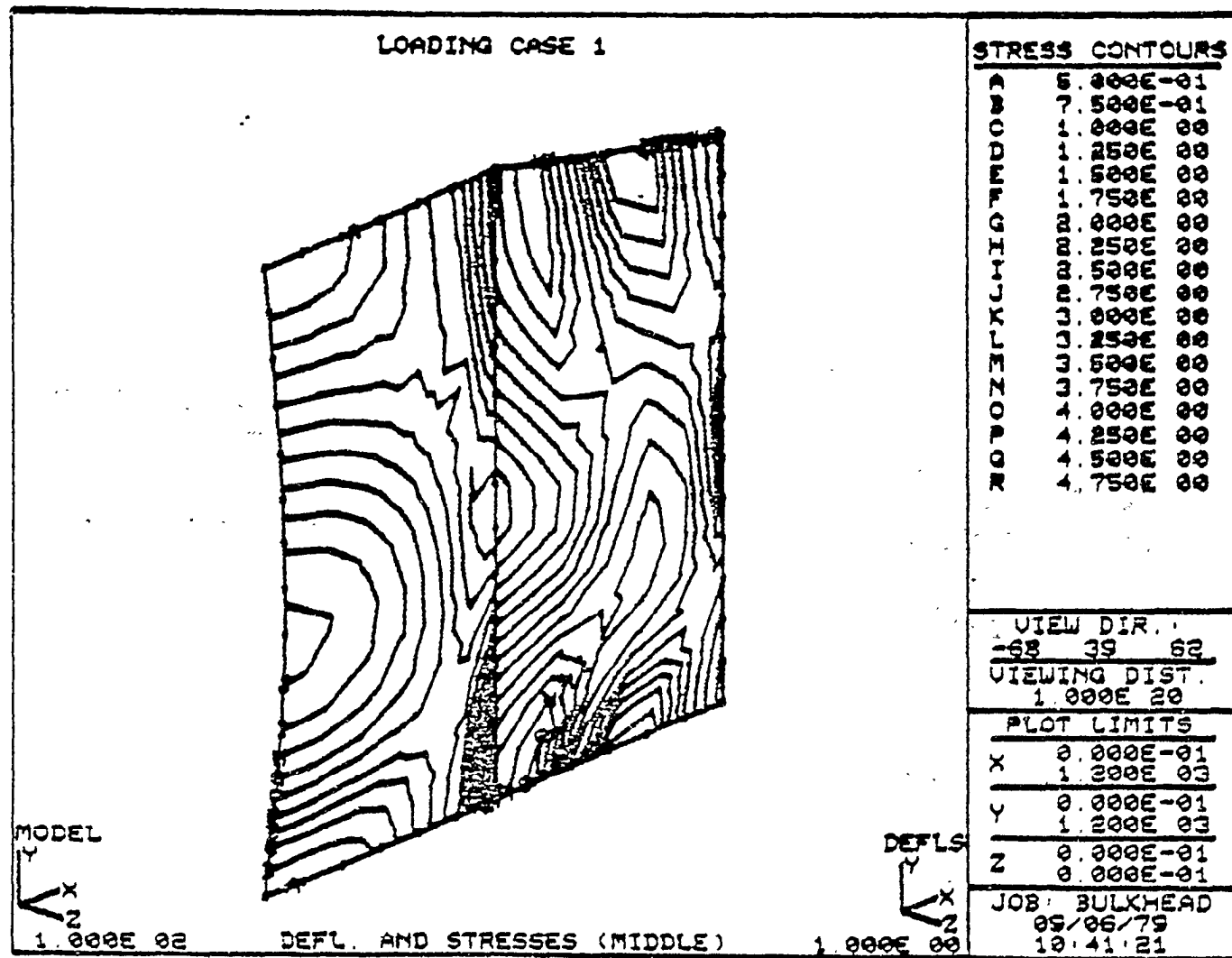
Figure 6. Von-Mises Stress Contours in Bulkhead Plating

APPLIED LOADS

QX ————— 0.000E-01

QY ————— 0.000E-01

QZ ————— 0.000E-01

GMX ————— 0.000E-01

ELEMENT NO. 243
LOADING CASE 1.

RESULTANT FORCES

N ————— 1.210E 05

UY ————— 2.100E 03

UZ ————— -1.670E 03

MX ————— -2.152E 02

BY ————— -7.040E 04

BZ ————— 7.201E 05

BEAM PROPERTIES

A = 3.870E 01
AQ= 1.700E 01
AP= 1.504E 01
IP= 3.740E 03
IQ= 6.010E 02
J = 6.240E 09
ZQ= 0.000E-01
YQ= 2.150E 01
ZO= 0.000E-01
YO= 3.000E 01
AL= 0.000E-01

YIELD STRESS
0.000E-01

BEAM FORCES

N = 1.210E 05
UY= 2.100E 03
UZ=-1.670E 03
MX=-2.152E 02
BY=-4.374E-01
BZ= 6.329E 05

152

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Figure 7. Load, Shear Force and Moment Diagrams for Typical
Stiffener Element
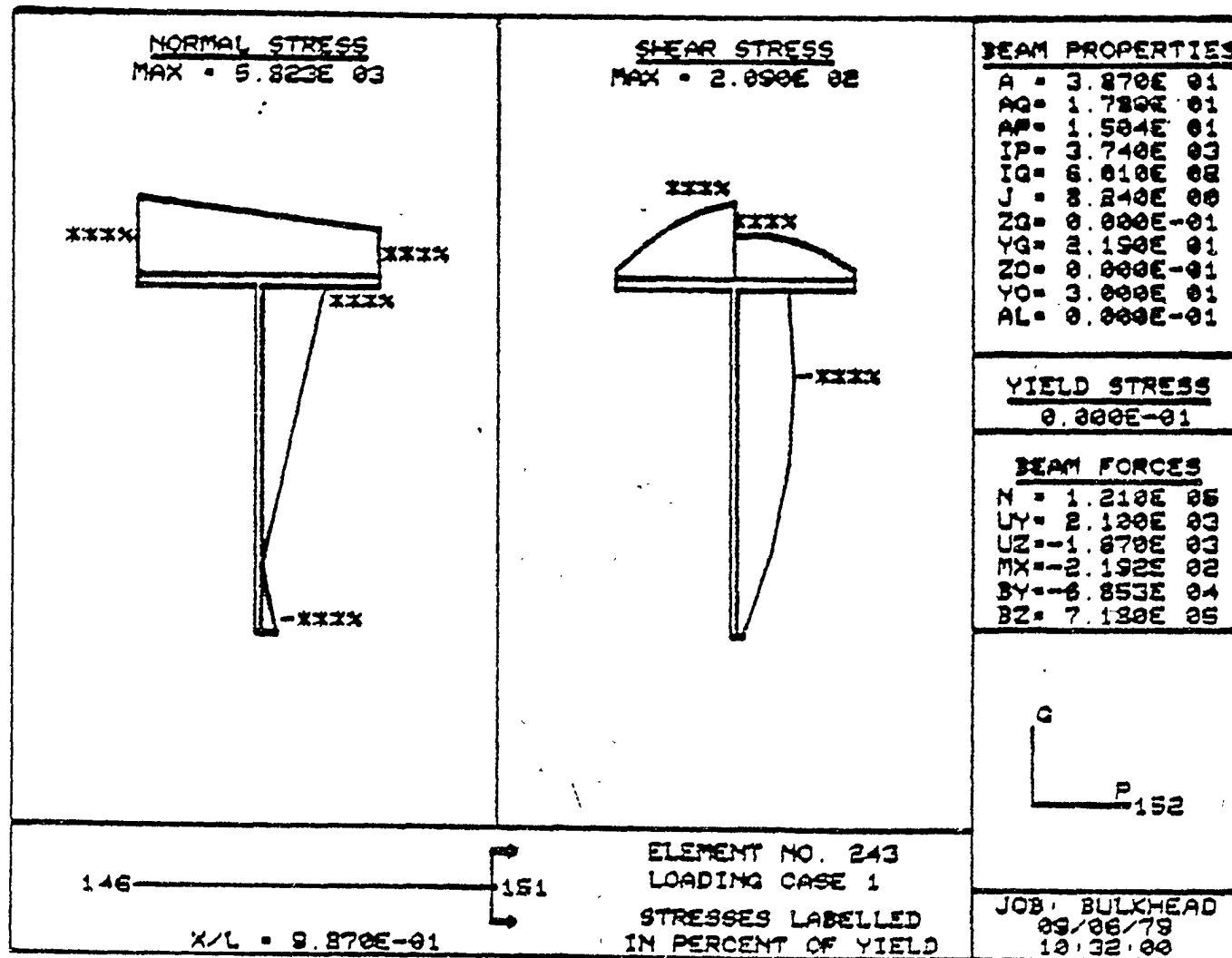
Figure 8. 'Detailed Stress Distribution on Beam Cross-section
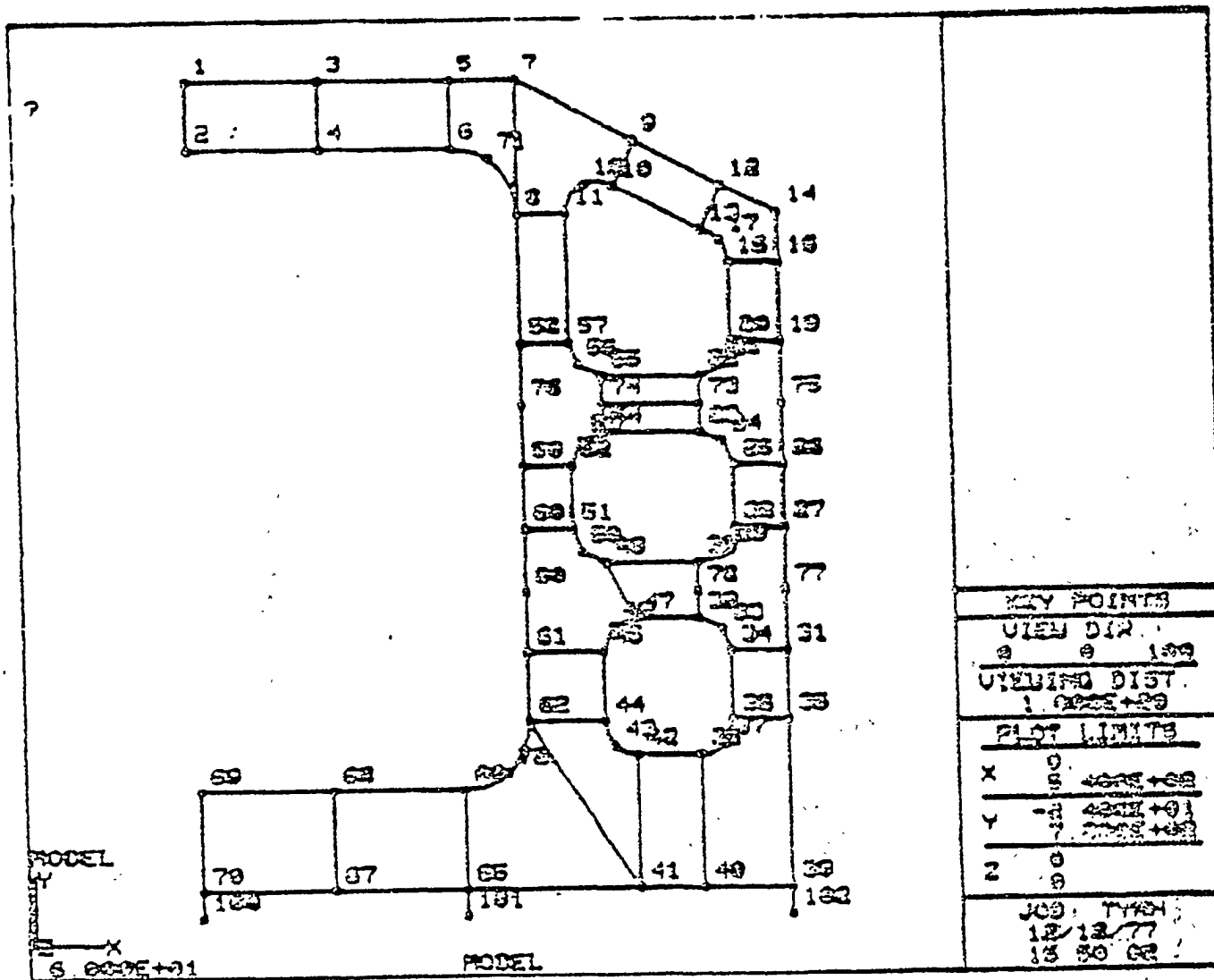
Figure 9. Subdivision of Webframe into Grids
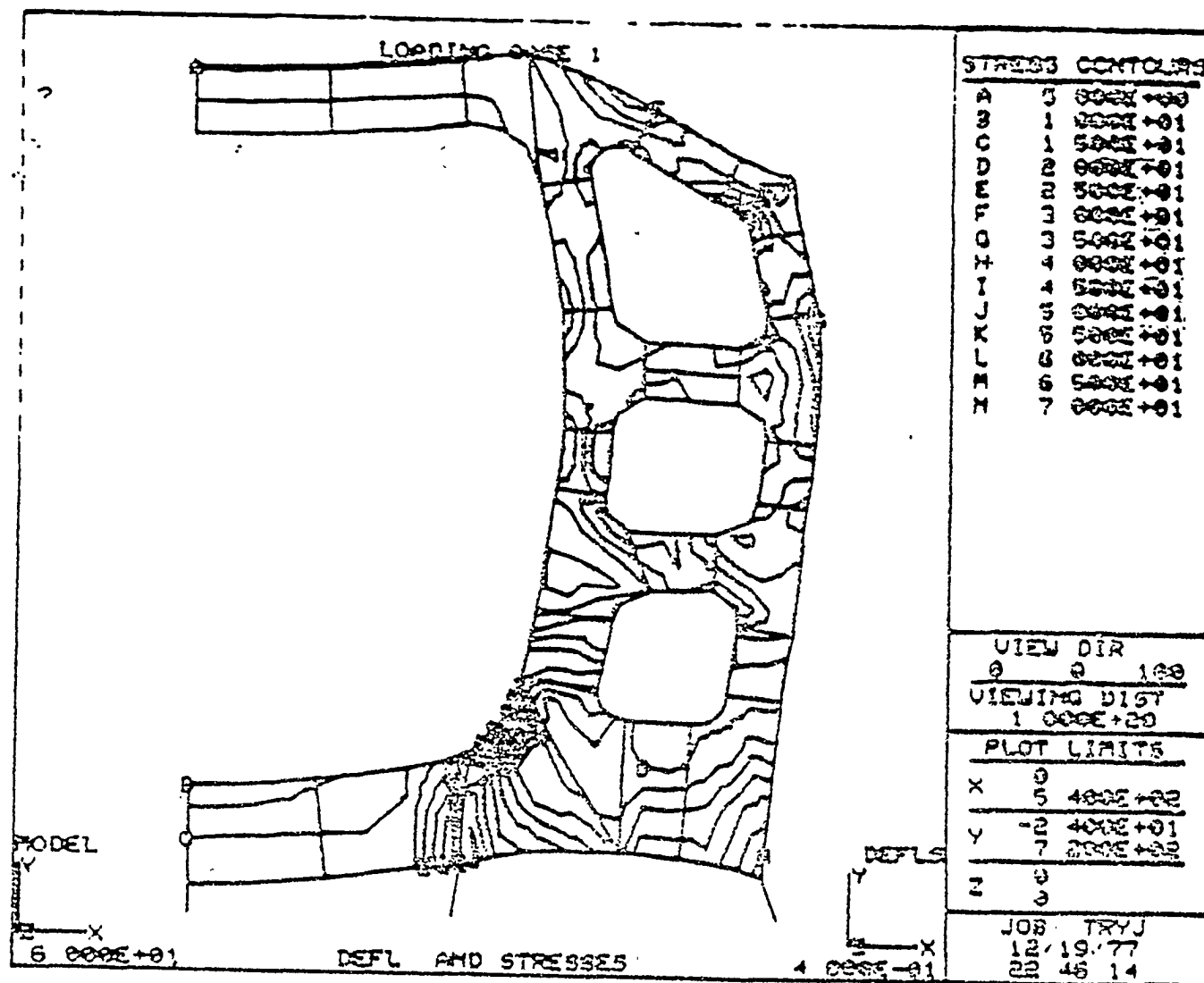
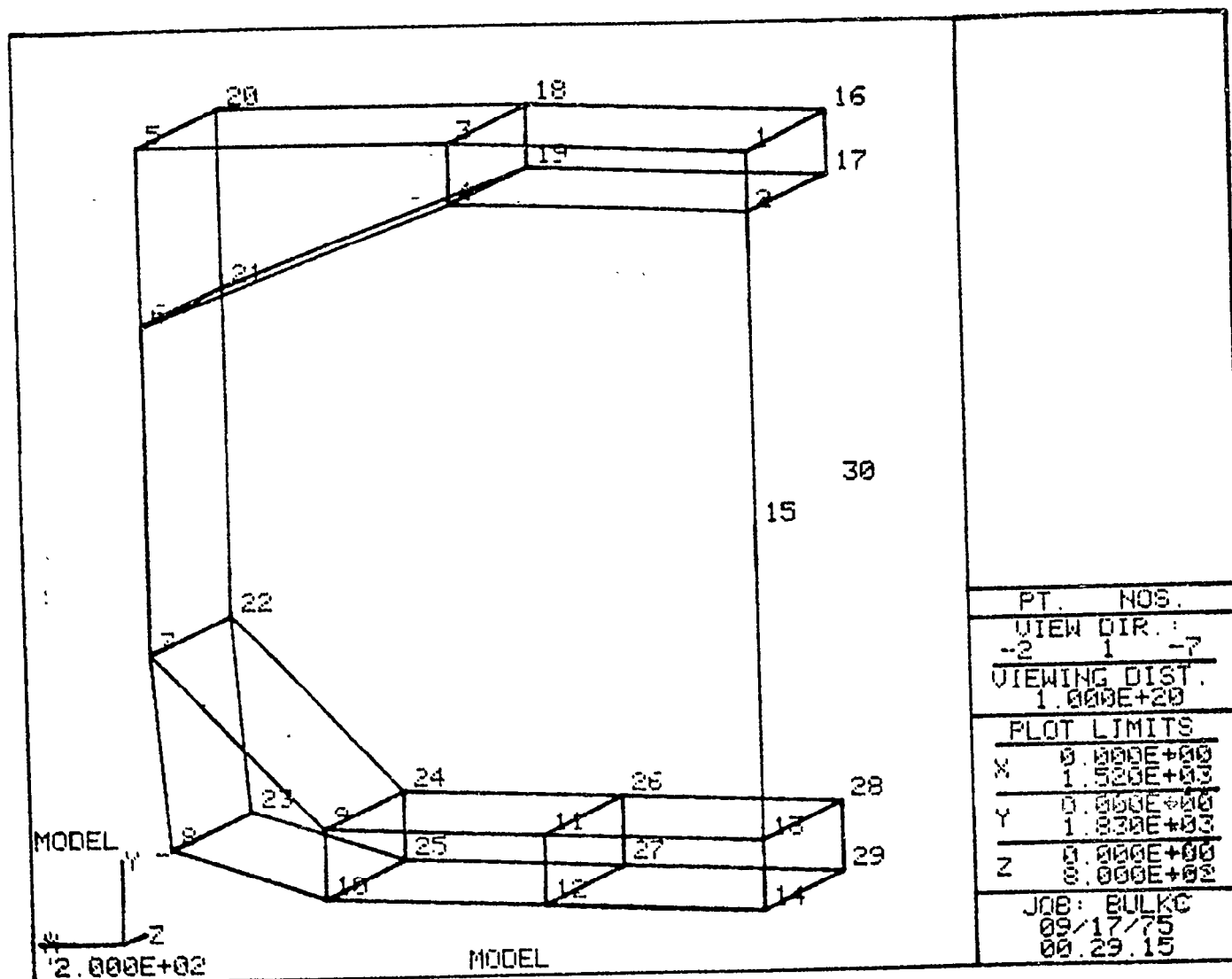Figure 10. Stress Contours in Webframe Structure

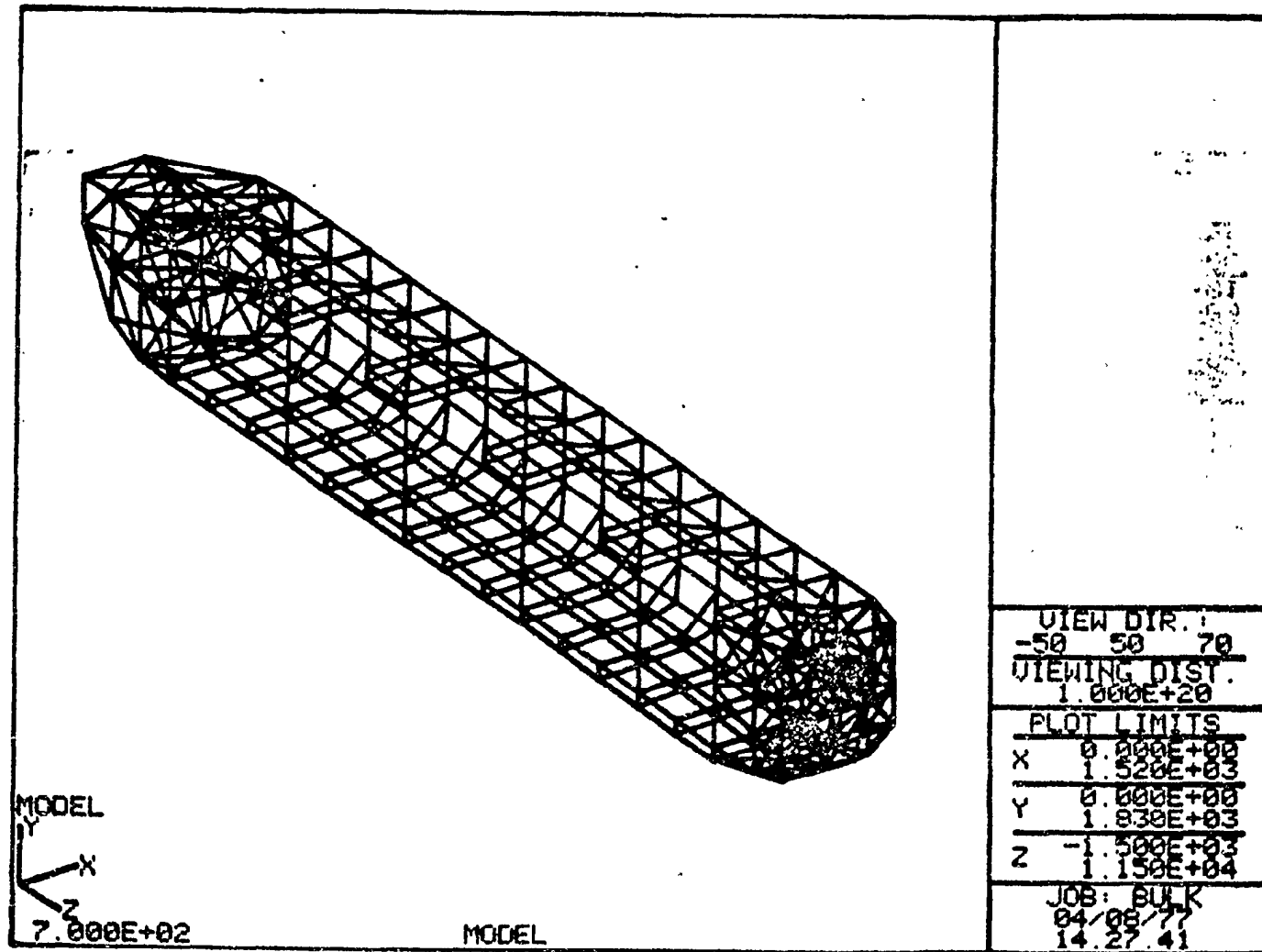Figure 11. Subdivision of Bulk Carrier Bay into Substructures
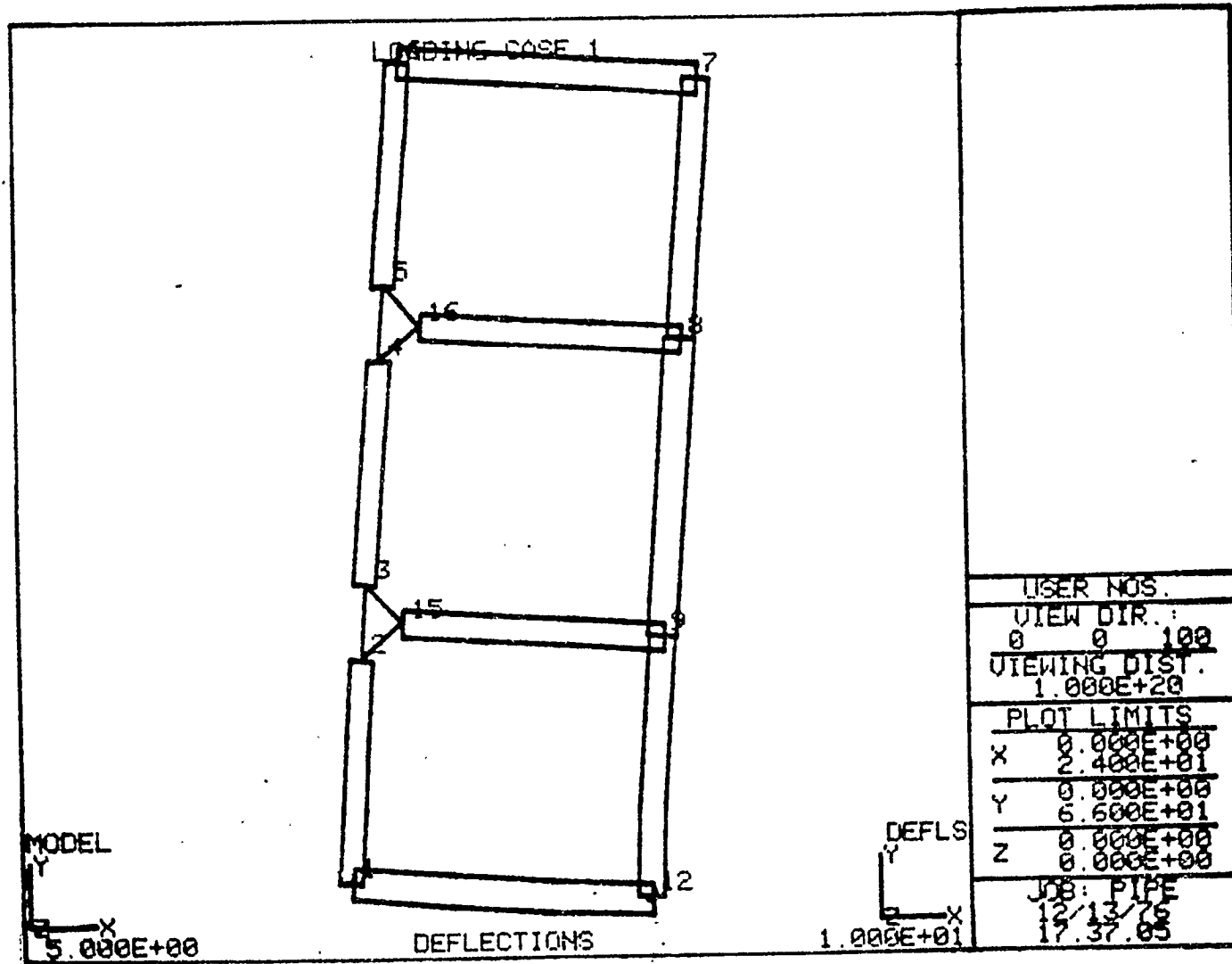
Figure 12. Complete Bulk Carrier Model

Figure 13. Two-Dimensional Tubular Frame Modeled Combining
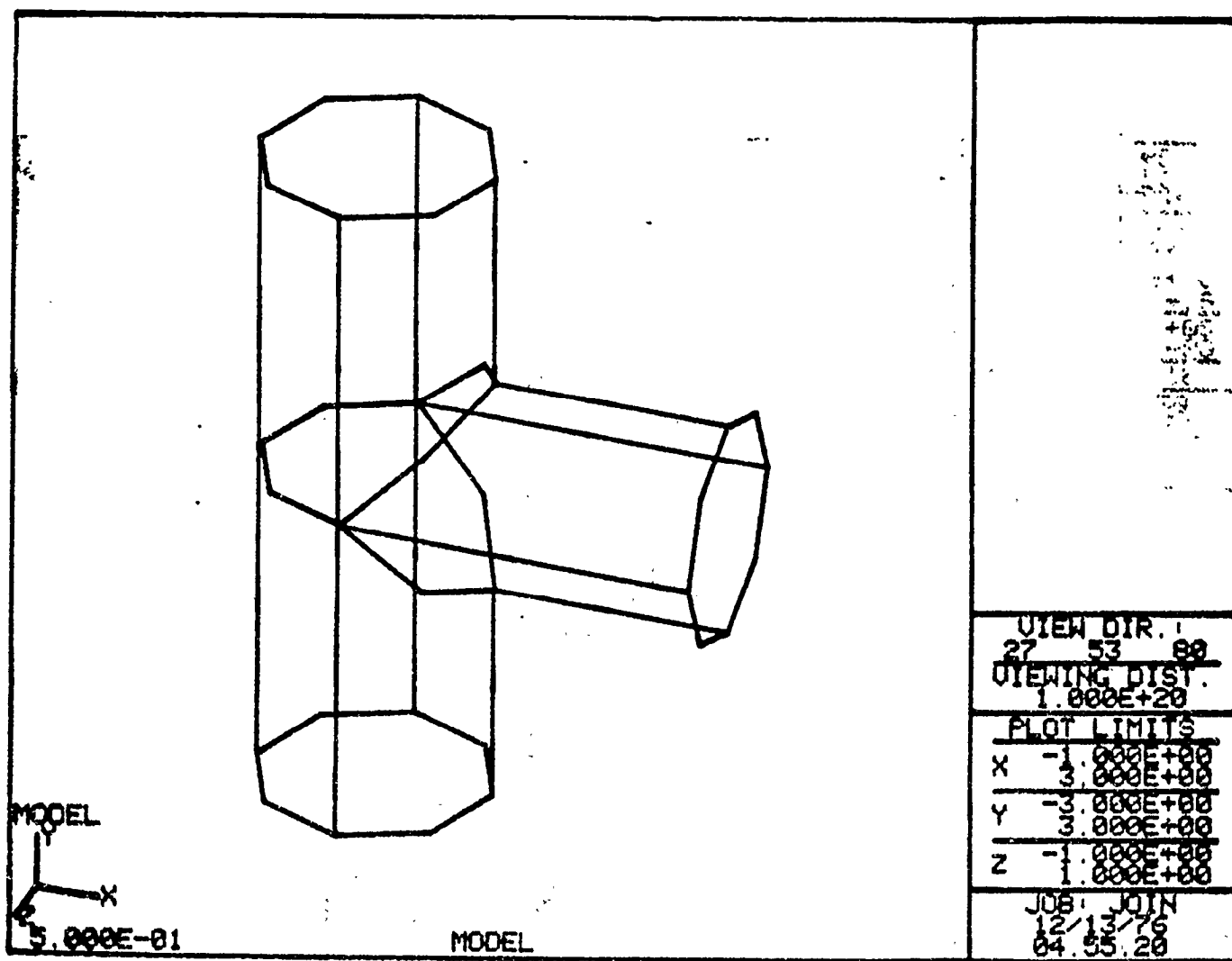Beam Elements and Constrained Substructures

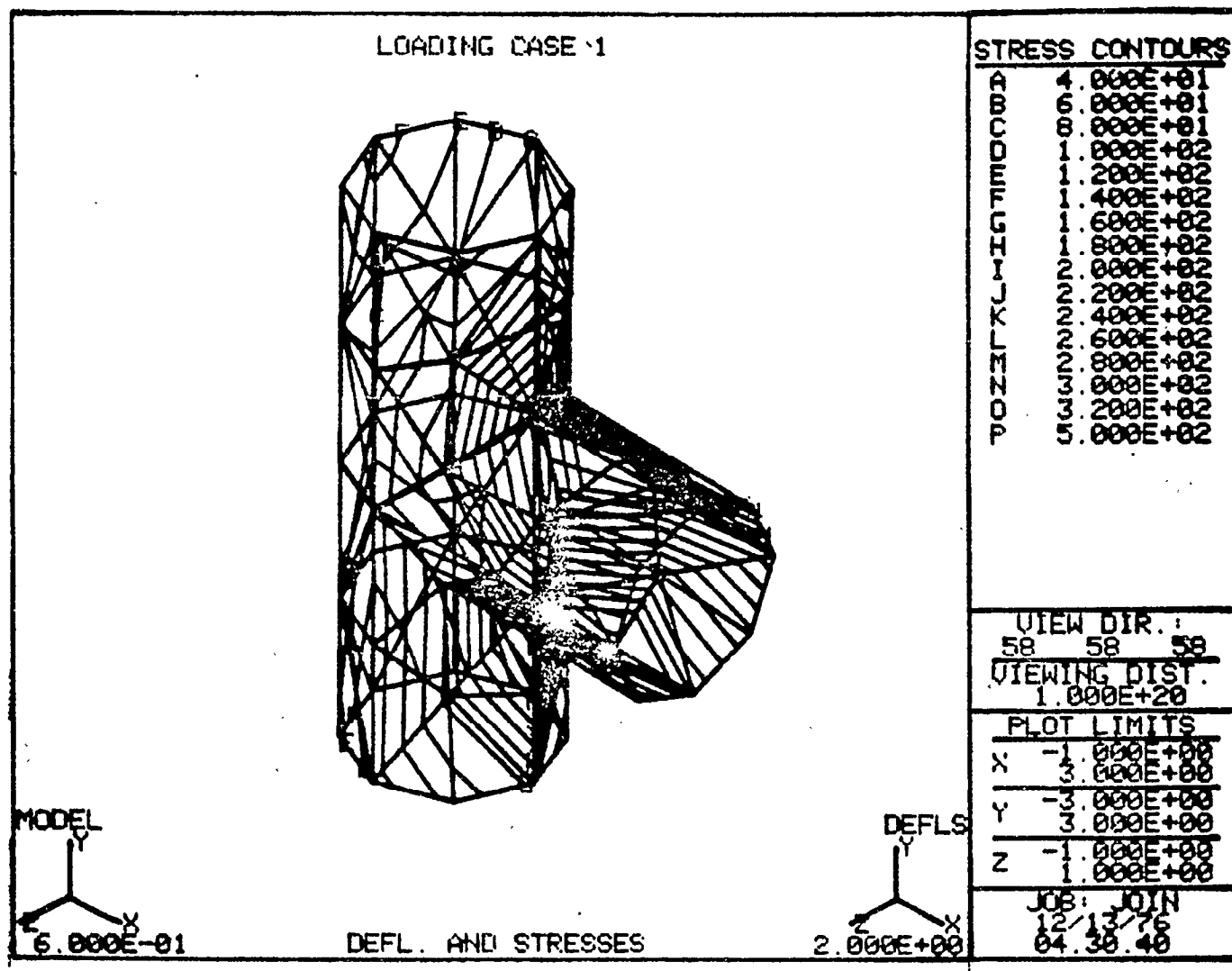Figure 14. Outline of Grids Used to Model Tubular Joint

Figure 15. Detailed Stress Distribution in Tubular Joint

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